§19. Thermal Behavior of the Helical Coil Conductor

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Disturbances in superconducting magnets are generally distributed in actual magnets, because the major origin of disturbances is an electromagnetic force, which should move rigid conductors in some length at the same time, not in a specific point. This movement causes plural separated disturbances by friction at insulating spacers at the same time in pool-cooled magnets.

We carried out the experiment to investigate the difference between the Minimum Quench Energy (MQE) with point disturbances and that with distributed disturbances. We installed several heaters along the conductor to simulate distributed disturbances. The heaters were placed beneath insulation spacers in order not to change the exposure rate of the conductor. Figure 1 shows a schematic drawing of the confguration of this experiment. Experimental parameters were operating current of the conductor sample, bias magnetic field, heating power, and pulse duration.

Total input energy at which the transition to a normal state occurred by heat pulse were plotted in Figure 2. The ratio of the energy was constant at 1:2:3, when the number of heating spots is changed as 1:3:5. The minimum energy density per heating spots to cause the transition to normal state, (MQE_{dis}), decreased with the number of the heating spots. The dependence can be estimated from the experimental results as following

$$MQE_{point} : MQE_{dis} = 1 : \frac{n+1}{2n} , \qquad (1)$$

where MQE_{point} is the minimum quench energy against point disturbance and n is the number of heating spots. When the n is sufficiently large, MQE_{dis} converges as following,

$$\lim_{n \to \infty} MQE_{dis} = \frac{1}{2} \cdot MQE_{point} \quad . \qquad (2)$$

Assuming the characteristic length l_{th} of temperature variation along the conductor, and the exposed length l_{ex} of the conductor per one cooling channel, the relation between l_{th} and l_{ex} determines the relation between MQE_{dis} and MQE_{point}. Case (1) ; when $l_{th} << l_{ex}$: $MQE_{dis} = MQE_{point}$, because one cooling channel is large enough to remove the heat energy from two adjacent heating spots. Since the cooling effect is very large, each heating spot can be considered to be completely independent on each other. Case (2) ; when $l_{th} \sim l_{ex}$: $MQE_{dis} = (1/2) \cdot MQE_{point}$, because one cooling channel has comparable size to remove the heat energy from one heating spots. The experimental condition corresponds to this region; temperature rise from bath temperature to T_{cs} at one heating spot is effectively cooled by one cooling channel. Case (3) ; when $l_{th} >> l_{ex}$: $MQE_{dis} \sim (1/n) \cdot MQE_{point}$, because one cooling channel does not have the size large enough to remove the heat energy from even one heating spot. Since the cooling effect is small, the heating effect accumulates according to the number of heating spots.

These results can be used to predict a minimum quench energy when distributed disturbances occur in actual magnets.

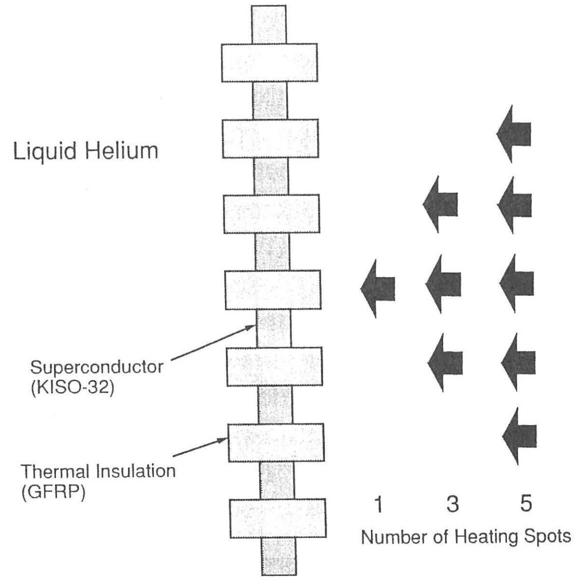

Fig. 1 Concept of distributed pulse heating.

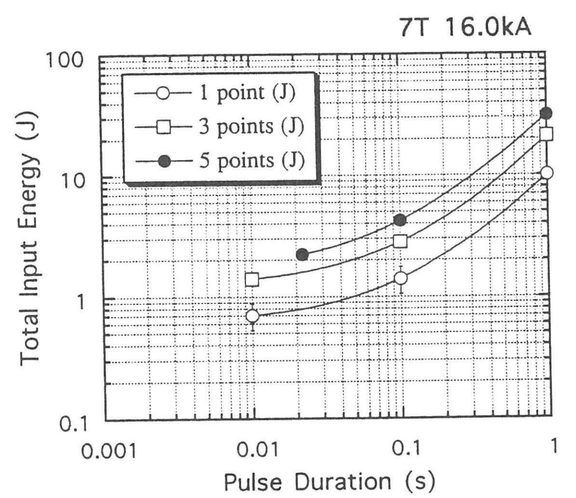

Fig. 2 Total input energy to the conductor subjected to distributed disturbances.